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DESIGN AND ANALYSIS OF TRESTLE HYDRAULIC JACK USING FINITE ELEMENT METHOD

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ABSTRACT

A jack is a device that used to lift heavy loads for automobile vehicles by the application of a much smaller force. In this work designed a new type of hydraulic jack with trestle feature. The new model was designed based on numerical calculation with loading and no loading condition also FEA model of trestle hydraulic jack has been created using solid works software according to design values. The FEA model was meshed and analyzed with loading condition using FEA code ANSYS 15.0 software, finally concluded that trestle hydraulic jack is suitable for lifting the heavy load (up to 50,000 N) automobile vehicle.

KEYWORDS: Trestle Hydraulic Jack, Design and Selection of Materials, LAME'S Equation, Lever Mechanism & FEA

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Original Article

1. INTRODUCTION

Jacks can be usually classified based on the type of force they employ: mechanical or hydraulic. Mechanical jacks lift heavy, light vehicles and are rated based on lifting capacity (for example, the number of tons it can lift). Hydraulic jacks are stronger than the mechanical jacks and can lift heavier loads with applying small effort, its classified bottle jacks, and floor jacks. Hydraulic jacks depend on force generated by pressure which is operating based on Pascal's law. Its states that the intensity of pressure at any point in a fluid at rest are same in all direction. If two cylinders (a large and a small one) are connected and force is applied to one cylinder, equal pressure is generated in both cylinders. However, because one cylinder has a larger area, the force the larger cylinder produces will be higher, although the pressure in the two cylinders will remain the same. Gurudev mute et al (7) had designed a telescopic hydraulic cylinder for 1000 kg capacity with suitable design parameters and base wheels finally concluded that the design is suitable for lifting the heavy load. K.sainath et al (3) had designed mechanical hydraulic jack for 6 ton capacity with numerical and breakeven analysis finally concluded that the designed model is suitable for lifting up to 6ton weight. Nitinchandra R.Patel et al (6) had designed a toggle jack using numerical and material optimization for various parts of toggle jack, finally concluded that the designed model is in the safety region.

2. CLASSIFICATION OF HYDRAULIC JACK

According to the source of power

- Manually operated jacks (hand or pedal-operated)
- Power operated jacks (hydraulic pump is used)

According to the lift of ram

- High lift
- Medium lift
- Low lift

According to the arrangement of the cylinder

- Vertical
- Horizontal
- Inclined

According to the number of cylinders

- Single cylinder
- Multi-cylinder
- Telescopic cylinder

According to the construction

- Floor mounted jack
- Bottle jack
- Trolley jack
- Trestle Hydraulic Jack

3. WORKING OF TRESTLE HYDRAULIC JACK

Hydraulic jack has been developed for small and medium automobile vehicles also its required semi-skilled labors for operating this device. Because of fixing the axle and keeping the correct position for avoiding slippage. In order to avoid such disadvantages the new model Trestle hydraulic jack has been developed. The existing trestle jack was designed without hand lever but the new trestle jack designed with a hydraulic cylinder with hand lever included with trestle future. Normally hydraulic jack is operating methodwhen the handle is operated like up and down movement of the piston so the vehicle lifts from the ground. In the trestle jack, the curved surface used to lift the vehicle with a small reverse movement of the vehicle as shown in the figure 1.in hydraulic jack and trestle, jack has some disadvantages. In order to overcome such dis advantages this trestle hydraulic has been designed in such a way that it can be used to lift the vehicle very smoothly without any impact force.

Figure 1: Existing Model of Trestle Jack (without Hydraulic Cylinder)

The new model trestle hydraulic jack consists of a plunger cylinder and it's inside side ram cylinder. These two cylinders are mounted on the base which is made of mild steel. Plunger cylinder consists of a plunger which is used to build up the pressure by operating the handle. Plunger cylinder consists of two non-return valves i.e. one for suction and other for delivery. Ram cylinder consists of ram and tops its part curved surface plate as shown in the figure 2 which lifts the load. The ram cylinder connected to the delivery valve of plunger cylinder. It is also consists of lowering screw this is nothing but a hand operated valve used for releasing the pressure in the ram cylinder forget down the load. Moreover the curved surface plate touched with wheel axle of the vehicle as shown in the figure 1 and move the vehicle little bit towards back it's automatically lifted because of trestle future of the jack. After lifting the vehicle the hand lever should be operated and vehicles lift the desired level.

3.1. CAD model of Trestle Hydraulic Jack

The new model trestle hydraulic jack CAD model is shown in figure 1. It has a piston and ram cylinder with handle also with trestle future.

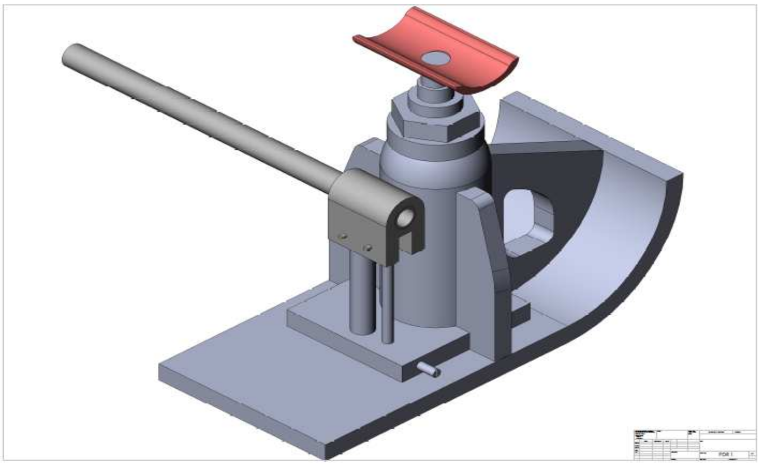

Figure 2: Trestle Hydraulic Jack

4. DESIGN OF TRESTLE HYDRAULIC JACK

4.1Design Considerations& Methodology

Load (W) = 05 ton (50,000N)

- OPERATING PRESSURE (p) = force/area = 50,000/ $\pi/4*D^2$ = $23.82 * 10^6$ N/m^2
- Lift range (L) =14 inch = 3500 mm

- Man effort put on the handle (e) = 11 Kg
- Permissible tensile stress of mild steel (σt) = 120 N/mm2
- No. of strokes for lifting load (n) = 100
- Permissible shear stress of mild steel (τ) = 20 N/mm2
- Permissible compressive stress of mild steel (σc) = 20 N/mm2
- Permissible compressive stress of cast iron (σCI) = 120 N/mm2
- Permissible shear stress of cast iron (τCI) = 35 N/mm2

4.2 Design of Ram Cylinder

It is a cylinder in which produces a slideway to the ram. The ram cylinder is made up of mild steel

Let, d = inner diameter of ram cylinder = 47mm

D = outer diameter of ram cylinder = 67 mm

P = pressure acting on cylinder =23.82 Mpa

W = load =50,000 N

T = thickness of ram cylinder = 20 mm

4.3. Design of Plunger Cylinder

The plunger cylinder is made up of mild steel and is mounted on the base plate. It provides slide way to the plunger in order to build up the pressure.

Let dp= inside dia of plunger cylinder = 12 mm

tp = thickness of plunger cylinder Assume the thickness of plunger cylinder (tp) = 10 mm

By using thickness and inside diameter, we can calculate the outer diameter of plunger cylinder Dp =dp + 2t = 12+2(10) = 32 mm

Dp = outside dia of plunger cylinder = 32 mm

Tensile strength of mild steel (σt) = 120 N/mm2

Height of plunger cylinder = 110 mm

Without Loading Condition

PressureP_p = F/A = 122/ $(0.012)^2$= 1.08 * 10^6 N/m^2

By LAME'S Equation (Consider with Loading Condition)

$$\sigma_t = \frac{D_i^2 * P_r}{D_o^2 - D_i^2}\left(1 + \frac{D_o^2}{D_i^2}\right)$$

$$= \frac{(0.047)^2 (28.22*10^6)}{(.067^2 - 0.047^2)}\left(1 + \frac{.067^2}{.047^2}\right)$$

$$\sigma_t = 84.66*10^3 N/m^2$$

$\sigma t < P_r$

Hence the induced tensile strength of M.S. is less than the permissible value.

So, the design is safe.

4.4. Design of Plunger

Let the plunger is made up of mild steel which reciprocates in plunger cylinder to increase the pressure of the oil.

Let, W = load acting on plunger = 50,000 N

dp = diameter of plunger = 12 mm

Load acting on plunger = pressure × area = 12×122 = 1464 N = 149.3 kg

We taken Load acting on the plunger =150 kg

4.5. Plunger Displacement

We know that Velocity ratio (V.R.) = Assume V.R. = 150;

Let us assume plunger displacement = 15 cm

4.6. Design of Lever

A lever is made up of mild steel and is used to apply load on the plunger. It is attached to the plunger with the help of pivot.

Assumptions, 1. Effort put on lever by man = 25 lb = 11 kg

Force acting on rod or lever = L/(L-X) * F_x = 200/ (200-20) * 110 = 122 N = 12 kg

Required Distance from Fulcrum to load = 180 mm

Total length of lever = 200 mm

Effort put on lever by man = 12 kg

Outer dia of lever = 25 mm

Inner dia of lever = 20 mm

Lever is made up of mild steel.

Permissible tensile strength of mild steel (σt) = 120 N/mm2

4.6.1. With Loading Condition

F = P *A

F = 28.82 * 10^6 * π/4*$(0.012)^2$ = 3359.5 N = 330 kg.

Where M = maximum bending moment

I = moment of inertia = permissible tensile strength

Y = distance between outer most layer to neutral layer

Z = section modulus

Figure 3: Lever Mechanism of Hydraulic Jack

Let us take R_c= F= 330 kg

Ra + Rb = 330 kg

Ra + 11 = 130

Ra =330-11

Ra = 319 kg

Bending moment at C = 0

Bending moment at B = 319*9.81*0.20-(330*9.81*0.18) = 43.16 N-m (sagging)

Bending moment at A = 0

4.6.2. Without Loading Condition

F = P *A

F = 1.08 * 10^6 * π/4*$(0.012)^2$ = 122 N = 15 kg.

Let us take R_c= F= 15 kg

Ra + Rb = 15 kg

Ra + 11 = 15

Ra =15-11

Ra = 4 kg

Bending moment at C = 0

Bending moment at B = 4*9.81*0.20-(15*9.81*0.18) = -18.78 N-m = 18.78 N-m (hogging)

Bending moment at A = 0

Maximum bending moment is less than the designed value. Hence design is safe.

4.7. Design of Reservoir

The following assumptions are made for this design of reservoir

The volume of oil circulated in the system is 850 c.c

Volume of oil in the reservoir= 1150 c.c

L = height of reservoir = 170 mm

We adopt inner dia of reservoir (d) = 87mm

Assuming thickness of reservoir (d) = 4mm

Therefore outer dia of reservoir (Dr) = 95 mm

4.8. Design of Base

Fix the dimensions of base plate as l× b × tb = 430×200×20

Where l = length of base

b =width of base

t_b =thickness of base.

A base is made up of mild steel. Permissible compressive stress of M.S (σc) = 20 N/mm2

- Compressive area of base =154×138

  = 21252mm2

- Permissible shear stress of mild steel (τ) = 20 N/mm2
- Shearing area = π × d × tb = π × 47 × 20 =2953.1mm2

  Where d = inner dia of ram cylinder tb =thickness of the base plate

- Load acting on base = 50,000N
- Checking for compressive strength σc= 50,000/ 21252 =2.35 N/mm2

  The permissible compressive stress of mild steel (τ)> checking for compressive strength (σc)

- Checking for shear strength τ =50,000/ 2953.1 = 16.93 N/mm2

  The permissible shear stress of mild steel (τ)> checking for shear strength (σc)

  The induced shear and compressive stresses are less than the permissible valve. Hence the design is safe.

5. ANALYTICAL ANALYSIS OF TRESTLE HYDRAULIC JACK USING FEM

The FEA model of trestle hydraulic jack was drawn using Solo works software and its imported to FEA code ANSYS software, it's shown in the figure 3.

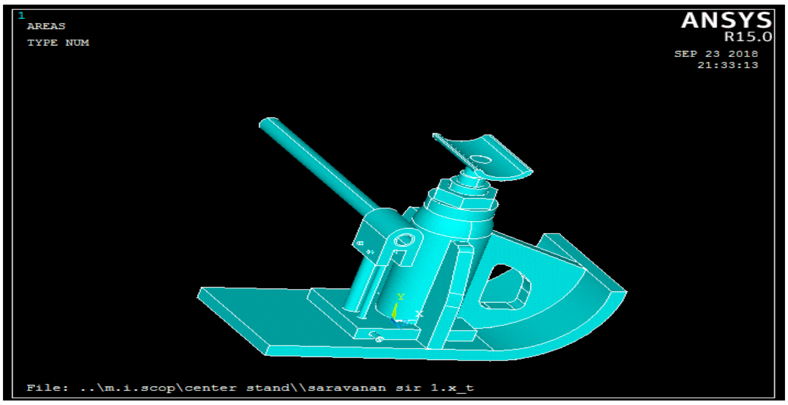

Figure 4: FEA Model of Trestle Hydraulic Jack

The FEA model of trestle hydraulic jack was meshed using FEA code ANSYS software, it's shown in the figure 4.

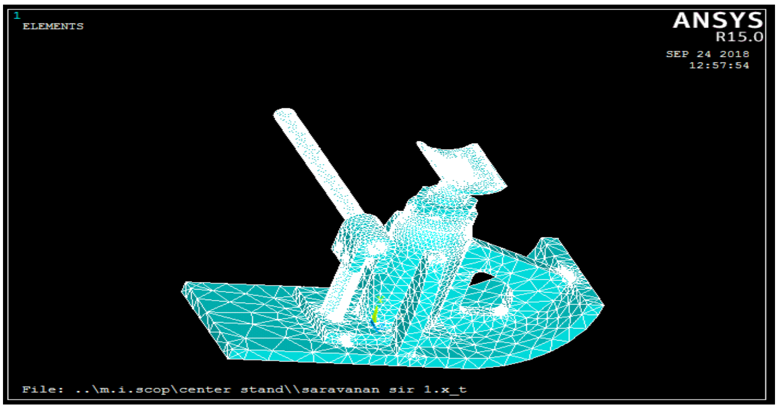

Figure 5: Meshed View of Trestle Hydraulic Jack

The Displacement vector sum (DSV) value was obtained using the FEA code ANSYS, it's shown in the figure 5. Also, it's observed that the maximum displacement has occurred at the top of the jack.

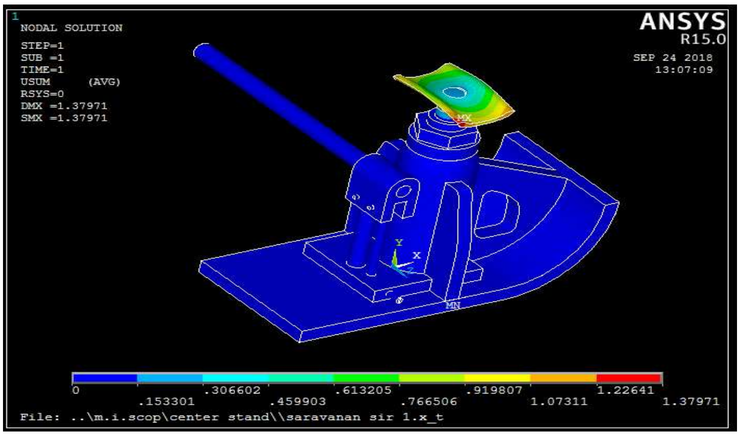

Figure 6: DSV (Deflection) of Trestle Hydraulic Jack

The Von-misses stress value was obtained using FEA code ANSYS, it's shown in the figure 6. Also, form the figure 6 it's observed that the maximum stress area in jack is very less. Its revealed that this model has withstood that amount of load.

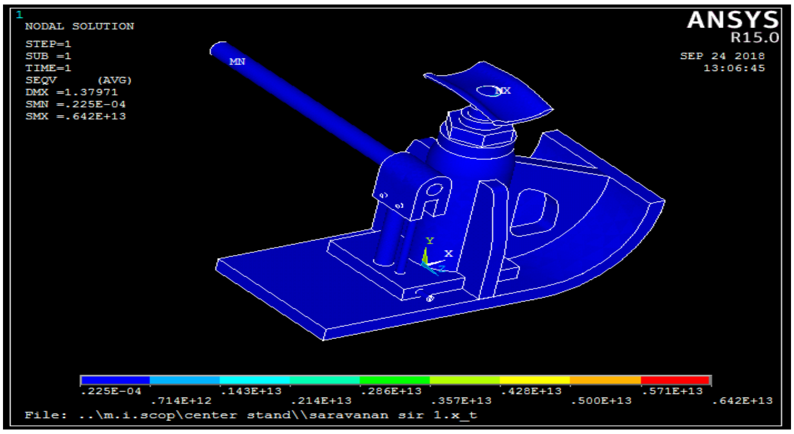

Figure 7: V. Stress of Trestle Hydraulic Jack

Von-misses strain value was obtained using FEA code ANSYS, it's shown in the figure 7.

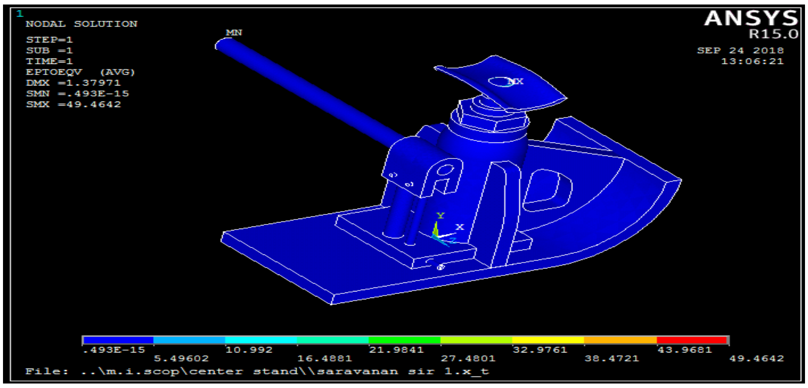

Figure 8: V. Strain of Trestle Hydraulic Jack

6. RESULT (ANALYTICAL VALUE)

The analytical value of displacement, stress and strain values are taken from FEA and tabulated in table 1.

Table 1: DSV, Stress and Strain Values of Trestle Hydraulic Jack (Analytical Method)

S. No	Load	Analysis	Analytical Value
1	50.000 N	Deflection	1.3 mm
2		Stress	64.2 Mpa
3		Strain	49.4 mm

Based on FEA results the various value of Deflection and load are taken and curve drawn its shown in the figure 7.

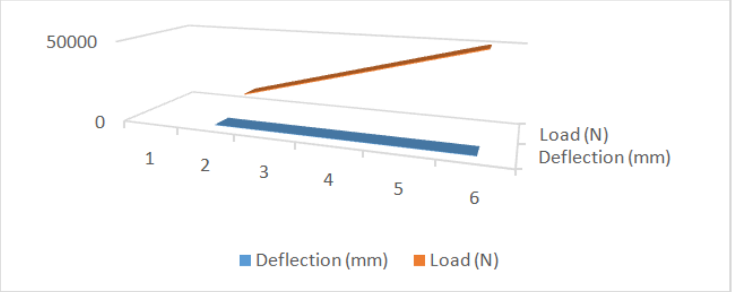

Figure 9: Load vs. Deflection Curve

Based on FEA results the various value of stress and load are taken and curve drawn its shown in the figure 8.

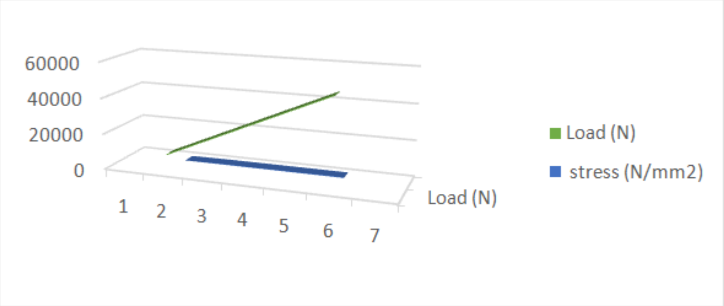

Figure 10: Load vs. Stress Curve

From the FEA result in table.1 and figure 9, 10 induced deflection and compressive stresses are less than the permissible valve. Hence the design is safe.

7. CONCLUSIONS

The following results can be investigated from the above analysis

- As per the Numerical value of the stress value of Trestle Hydraulic Jack under loading, condition is less than the design value.
- The Analytical value of stress and strain and deflection values of Trestle Hydraulic Jack is less than the design value. From that it can be concluded that the designed Trestle Hydraulic Jack is under the safety region when it's in under loading condition.
- Numerical result and analytical result both are similar. So the design parameters are verified numerical and analytically from that it concluded that design is safe.
- From that, above Numerical and Analytical (FEA) analysis concluded that Trestle Hydraulic Jack is suitable for heavy load (up to 50,000 N) lifting Application.

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